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Review of existing energy retrofit decision for homeowners.

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Review

Review of Existing Energy Retrofit Decision Tools for Homeowners

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Abstract: Energy retrofit tools are considered by many countries as one of the strongest incentives to encourage homeowners to invest in energy renovation. These tools help homeowners to get an initial overview of suitable retrofit measures. Although a large number of energy retrofit tools have been developed to inspire and educate homeowners, energy renovation by individual homeowners is still lagging and the impact of current tools is insufficient as awareness and information issues remain one of main obstacles that hinder the uptake of energy retrofitting schemes. This research extends the current knowledge by analysing the characteristics of 19 tools from 10 different countries. The selected tools were analysed in terms of energy calculation methods, features, generation and range of retrofit measures, evaluation criteria, and indications on financial support. The review indicates that: (1) most toolkits use empirical data-driven methods, pre-simulated databases, and normative calculation methods; (2) few tools generate long-term integrated renovation packages; (3) technological, social, and aesthetic aspects are rarely taken into consideration; (4) the generation of funding options varies between the existing tools; (5) most toolkits do not suggest specific retrofit solutions adapted to traditional buildings; and (6) preferences of homeowners in terms of evaluation criteria are often neglected.

Keywords: energy retrofit; decision tools; homeowners; energy efficiency; web-based applications; energy calculations

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1. Introduction

Globally, the building sector consumes almost 30% of all global energy used [1]. The number of countries announcing pledges to achieve net-zero emissions by 2050 continues to grow. Reaching the net-zero target by 2050 means that close to half of the existing building stock in advanced economies is retrofitted by 2030, and one-third is retrofitted elsewhere [2].

Although most countries have made significant efforts to promote the decarbonisation of the building stock, worldwide implementation of energy efficiency measures in existing buildings is lagging and fall well short of what is required to bring global energy-related carbon dioxide emissions to net zero by 2050. The International Energy Agency (IEA) reports that the rate of progress in deep energy efficiency renovations of existing buildings is slow, with an annual of less than 1% of the existing building stock [3]. To decarbonise the global existing building stock by 2050, renovation rates in industrialised countries should increase to an average of 2% of existing stock per year by 2025, and to 3% by 2040 while renovation rates in developing countries should reach 1.5% by 2025 and 2% by 2040. Furthermore, the depth of renovation should be increased to enable deep energy renovations that reduce the energy consumption of existing buildings by 30–50% or more [1].

Many countries have introduced relevant retrofit policy instruments (RPIs) to accelerate energy renovations in residential buildings. Zhang et al. [4] have summarized and compared various RPIs for residential buildings across 11 different countries. The investigated RPIs were grouped into four categories: direction and command instruments (overall retrofit strategies, targets, and requirements), assessment and disclosure instruments (tools for benchmarking buildings), research and service instruments (provide access to retrofit information and increase occupants' awareness), and financial incentives (grants, rebates, loans, and tax credits).

Esser et al. [5] have indicated that information on cost and amount of energy consumption on the energy bill is the strongest incentive to encourage homeowners to invest in energy renovation. The public and private sector have produced a large number of energy efficiency decision tools to encourage homeowners to invest in energy efficiency measures by providing them information on energy improvement solutions suitable for their homes. For instance, the online tool 1 2 3 Réno has been developed as part of the European project MARIE [6]. The tool generates energy improvement packages according to different renovation objectives and to different typologies of homes in the Mediterranean and alpine regions in France. Additionally, Quickscan tool [7] has been developed as part of the European funded Interreg NWE ACE-Retrofitting (Accelerating Condominium Energy Retrofitting) project. The tool allows homeowners to get an initial overview of suitable retrofit measures that could be installed within their building. Home Energy Check (HEC) [8] has been developed as part of Request2Action project which is co-funded by the Intelligent Energy Europe. HEC allows Greek homeowners to simulate energy behaviour, rating, and CO_2 emissions of their homes. In the USA different tools such as Home Energy Yardstick [9] and MyHomeEQ [10] were developed to motivate and inspire homeowners by allowing them to compare their homes energy usage against other similar homes in the region and providing them information on energy improvement possibilities.

Although a myriad of decision tools has been produced to inform and educate homeowners about energy retrofitting, global energy renovation by individual homeowners is still lagging and the impact of current tools is insufficient as awareness and information issues remain one of the main obstacles that hinder the uptake of energy retrofitting schemes at the level required to decarbonise the global existing building stock by 2050. Many studies investigated existing energy retrofit tools. Crawley et al. [11] studied 20 different standalone energy analysis software and presented a comprehensive comparison regarding their main functional capabilities. Tahsildoost and Zomorodian [12] investigated 25 web-based energy simulation tools with a focus on their general information, calculation methods, required inputs, and output results. Lee et al. [13] reviewed 18 existing tools available for retrofitting purposes, targeting small and medium size office and retail buildings. This study indicated that easy-to-use and readily accessible retrofit assessment tools are needed to help small and medium building owners to make wise decisions by providing information about energy savings and economic benefits from the investment in energy efficiency retrofits. In addition, Gonzalez-Caceres et al. [14] studied 18 tools used for renovation purposes specifying their characteristics such as main goal, target audience, methodology, and novelty.

The existing reviews on building energy retrofitting tools focus on decision tools that target a wide audience of building stakeholders (e.g., architects, designers, policymakers, and municipalities) while energy retrofit applications designed specifically to inform and inspire homeowners have not been studied. To the best knowledge of the authors, none of the existing studies investigates the characteristics of current decision tools available for homeowners, such as features and calculation methods. This research extends the current knowledge by analysing existing approaches and trends used for developing energy retrofitting decision support tools that aim to inspire homeowners. A total of 19 tools from 10 different countries were selected for this review. Our review of building retrofit toolkits was conducted to better understand different characteristics of existing tools, such as inputs, features, calculation methods, generation and range of retrofit measures, evaluation criteria, and financial support. This study provides developers opportunities to improve the quality of the information provided by existing tools (proposing long-term integrated renovation packages for homeowners, considering the preferences of users, considering traditional buildings, and including social criteria), which could enhance their impacts on homeowner's motivation to undertake energy renovation works.

2. Methodology

To find relevant toolkits, literature searches of academic and grey English-language literature were performed. Grey literature included government reports, research reports, local councils' websites, banks' websites, newsletters, and bulletins. Literature searches were conducted using Google Scholar, Scopus, and Google engines with the combination of the following keywords," energy simulation, energy retrofit, energy renovation, building energy efficiency" and "tool, toolkit, calculator, web-based application, decision tool" and "home, homeowner, residential buildings". A total number of 39 toolkits were preliminarily selected and were then reduced to 19, considering the inclusion and exclusion criteria.

In the first step, web-based tools and stand-alone applications with the purpose of energy retrofitting in existing buildings were selected as the main inclusion criterion. The review included decision support tools developed by governments, research laboratories, universities, and private companies that are publicly accessible. In the next step, tools requiring complex energy simulation tools such as EnergyPlus [15] and DOE 2.0 [16] were excluded. Retrofit tools with the purpose of building energy calculation on either district [17], city [18] or regional [19] levels were also excluded and only the scale of single buildings was considered.

In addition, the review did not consider simplified decision tools that target building professionals (e.g., energy managers, architects, and engineers) in the residential sector such as TABULA [20], BEopt [21], EPIQR [22], INVESTIMMO [23], A56opt-tool [24], RenoFase tool [25], and EZ Retrofit [26] which were considered not appropriate for homeowners.

Furthermore, as this review focuses on energy retrofit tools that specifically target homeowners, it did not include tools that are designed for owners of commercial buildings such as EnergyIQ [27] and EnCompass [28].

Moreover, this study did not consider decision tools that deal only with one specific aspect of energy retrofitting such as solar panel calculators [29], airtightness assessors [30], insulation calculation tools [31], and home renewables selector tools [32] and instead only considered tools that suggest overall building improvements. Finally, some tools were excluded due to the lack of technical information concerning their calculation methods [33,34].

The final list of 19 tools from 10 different countries that were identified and selected for this review is indicated in Table 1. As the literature searches were performed using only English keywords, existing tools in other countries available in other languages were not included in this study. The selected tools were analysed in terms of energy calculation methods, main features, generation and range of retrofit measures, evaluation criteria, and indications on financial support.

Table 1. A list of the reviewed toolkits.

	Toolkit Name	Location
1	Check je huis	Belgium
2	Home energy saving tool	UK
3	Home Energy Yardstick	US
4	MyHomeEQ	Northern Illinois
5	Totalkredit's energy calculator	Denmark
6	Quickscan tool	Europe
7	SWAHO (Sustainability Weighting Assessment for Homeowners)	Canada
8	ALICE	France
9	INSPIRE	Europe

Table 1. *Cont.*

	Toolkit Name	Location
10	1 2 3 Réno	Mediterranean and alpine regions in France
11	Energihjem.dk	Denmark
12	Energy Efficiency Calculator	England
13	Home Energy Check (HEC)	Greece
14	Renovation configurator	Germany
15	SOLIHA autodiagnostic	France
16	Improve your home	Netherlands
17	4ECasa	Italy
18	Home energy saver	US
19	HOT2XP	Canada

3. Review of Existing Energy Retrofit Decision Tools for Homeowners

As indicated in Lee et al. [13], the decision tools for homeowners have been grouped according to their calculation methods for energy consumption (empirical data-driven methods, pre-simulated database, simplified normative calculation methods, and advanced calculation methods).

3.1. Empirical Data-Driven Methods

Data-driven methods are based on historical data such as real measured data and pre-defined databases. The main advantages of data-driven methods are the high running speed, ease of use, and high accuracy of the results. However, this type of calculation method is generally limited to a particular climate or type of building and requires having pre-defined data [13]. Tables 2 and 3 describe the characteristics of the empirically data-driven toolkits.

Table 2. A list of the toolkits using empirical data-driven methods with the general input requirements.

General Information	1. Check Je Huis	2. Home Energy Saving Tool	3. Home Energy Yardstick	4. MyHomeEQ	5. Totalkredit's Energy Calculator
URL	checkjehuis.stad.gent/	home-energy-saving-tool.halifax.co.uk/	energystar.gov/index.cfm?fuseaction=home_energy_yardstick.showgetstarted	myhomeeq.com	totalkredit.dk/energi/energiberegner/
Developer/Sponsor	Belgium	HALIFAX Energy Saving Trust	ENERGY STAR	Energy Impact Illinois	Norconsult Danish Energy Agency
Type	Web-based	Web-based	Web-based	Web-based	Web-based
Location	Belgium	UK	US	Northern Illinois	Denmark
Postcode	X	X	X	X	X
Calibration	X	X	X	X	X
Utility bills			X	X	
Occupant behaviour	X	X			
Preferences of user					
Simple building characteristics	x	x	X	X	X
Simple system characteristics	x	x	X		X
Detailed building characteristics	x	x			
Detailed system characteristics	x	x	X		

Simple building characteristics: This includes all or some of the following inputs: building type, age of the building, floor area, and the number of residents. Simple System Characteristics: This includes heating system, wall insulation, window type, and floor and roof characteristics. Detailed System and Building Characteristics goes beyond that listed in the simple category.

Table 3. A list of the toolkits using empirical data-driven statistical methods and highlighting energy calculation methods, main features, generation and range of retrofit measures, evaluation criteria, and indications on financial support.

Tools	Calculation Engine	Features	Retrofit Solution Categories	Generation of Retrofit Solutions	Evaluation Criteria	Indications on Financial Support
1. Check je huis	Estimates energy consumption according to average Ghent energy consumption, which is determined based on real data from Eandis.	An interactive interface makes it easy to show the impact of different measures.	Building envelope, energy-efficient equipment for heating and hot water, renewable energy.	Users select retrofit solutions.	EPC rating, Investment cost (€), energy loan (€/month), bonuses received (€), yearly energy savings (kWh/year), carbon reductions (kg), yearly bill savings (€/year).	Provides detailed calculations on bonuses and energy loans.
2. Home energy saving tool	Uses dynamic Engine—Energy Saving Trust's market-leading calculation engine developed by Energy Saving Trust's.	Gives a personalised action plan with estimates Energy Performance Certificate (EPC) rating. Takes into consideration the preference of users and generates solutions according to a limited budget.	Building envelope, energy efficient equipment for heating and hot water, electric lighting, renewable energy, occupant behaviour change	Automatically provides a list of renovation solutions that are evaluated individually.	Estimated cost (£), potential saving per year (£), green rating (qualitative), current and potential EPC band.	Indicates funding options that are not directly related to the selected retrofit solutions.
3. Home Energy Yardstick	The Yardstick score is based on data obtained from the U.S. Department of Energy's Residential Energy Consumption Survey (RECS).	Compares the real energy performance of a home along with that of similar homes based on the last 12 months of utility bills.	Building envelope, energy efficient equipment for heating and hot water, electric lighting, occupant behaviour change	Users select retrofit solutions.	The comparison is made through a simple metric that ranks a home on a 0 to 10 scale after adjusting for home size and age, occupant number, climate.	Does not provide indications on funding options.
4. MyHomeEQ	Results are based on municipal property assessor data associated with the address provided by the user and data on 1.1 million homes.	EQ score is measured based on the combined gas and electric usage divided by the square footage of a home. The tool includes normalisation due to weather differences in the calculation of EQ scores.	Building envelope, energy efficient equipment for heating, and cooling, occupant behaviour change	Automatically provides a list of renovation solutions that are evaluated individually.	EQ score, potential annual energy savings ($), how a home performs compared to similar homes (%), payback period (years), cost to implement improvement measures, potential annual energy savings per solution ($)	Does not provide indications on funding options.
5. Totalkredit's energy calculator	Results are based on energy label reports from the Danish Energy Agency and information from the Building and Housing Register (BBR).	Based on the address provided, the calculator suggests possible energy improvements. If the energy performance certificate linked to the provided address is not correct or unavailable, users can modify their information and a new calculation will be made based on BBR.	Building envelope, energy efficient equipment for heating, renewable energy	Automatically provides a list of renovation solutions that are evaluated individually.	Investment cost (Danish Kroner (DKK)), annual savings in CO 2 in tonnes, annual savings in money (DKK)	Indicates funding options that are not directly related to the selected retrofit solutions.

3.1.1. Check Je Huis

Check je huis was developed by the city of Ghent to motivate people to renovate their house in an energy-efficient manner. A simple interactive interface makes it easy to show the evaluation of different retrofit measures in terms of different criteria such as investment cost, available grants, yearly energy savings, yearly carbon reductions, and yearly bill savings. The tool estimates energy consumption according to the homeowner profile's (age of the house, type, etc.) which is linked to average Ghent energy consumption determined based on real data from Eandis. Users have also the option to enter their energy consumption if know [35].

3.1.2. Home Energy Saving Tool

The Home Energy Saving Tool was developed by Halifax (part of Lloyds Banking Group) to help homeowners reduce their energy consumption. The Home Energy Saving tool is powered by the Dynamic Engine—Energy Saving Trust's market-leading calculation engine developed by Energy Saving Trust's. The tool uses extensive reference data to model all possible combinations for a range of property archetypes [36]. The tool gives a personalised action plan with an estimated Energy Performance Certificate (EPC) rating. The tool presents the advantage compare to similar calculators to take into consideration the preference of users. It allows users to indicate which criterion (lower energy cost, reduce environmental impact, and improve EPC band) is the most important for them. In addition, the tool generates solutions according to a limited budget.

3.1.3. Home Energy Yardstick

The Home Energy Yardstick was developed by ENERGY STAR, the tool compares the real energy performance of a home compared to that of similar homes based on the last 12 months of utility bills. The comparison is made through a simple metric that ranks a home on a 0 to 10 scale after adjusting for home size and age, occupant number, and climate. The Yardstick score is based on data obtained from the U.S Department of Energy's Residential Energy Consumption Survey (RECS). The Yardstick tool uses a regression model developed from analysis of RECS to take into account the effects of local weather, home size, and the number of occupants on the energy score [9].

3.1.4. MyHomeEQ

MyHomeEQ was developed as part of the Energy Impact Illinois program. This tool was designed to provide a MyHomeEQ score for homeowners to compare their home energy usage against other similar homes in the region. The tool is highly accurate and is based on municipal property assessor data associated with the address provided by the user and data on 1.1 million homes to generate initial findings and recommendations for the home. Users have also the option to enter their home's characteristics where data from property assessor are not available. To further improve the accuracy of the tool, users could also provide their gas and electric utility account information. After indicating their addresses or home's characteristics, users received their Energy Quotient (EQ) score, potential annual energy savings, how their home compared to similar homes, payback period, and cost to implement the improvement. EQ score is measured based on the combined gas and electric usage divided by the square footage of a home. The tool also includes normalisation due to weather differences in the calculation of EQ scores [10].

3.1.5. Totalkredit's Energy Calculator

Totalkredit's energy calculator was by Norconsult in collaboration with Danish Energy Agency. Based on the address provided by the user, the calculator suggests possible energy improvements and evaluates them in terms of investment cost, annual energy savings, and annual carbon reduction. Energy consumption calculations are based on EPC reports from the Danish Energy Agency and information from the Building and Housing Register (BBR).

If a house has a valid EPC, the tool retrieves the information from the EPC's report. The user can correct the information from the EPC, and a new calculation is made based on BBR information. If a house does not have an EPC, the tool obtains the information from (BBR), and the Danish Energy Agency's New Heating Calculator [37].

3.2. Pre-Simulated Databases

In a pre-simulated database, detailed numerical models are generally used to simulate the energy performance of several combinations of building envelope, HVAC systems, and renewable energy integration. Decision tools that rely on pre-simulated databases are easy to use as they often require few inputs and are highly accurate as simulations are generally performed with advanced simulation engines such as Energy plus and Transys. However, thousands of energy simulation are necessary to build a database, which makes it extremely time-consuming to develop. Besides, such tools take into account only limited typologies of buildings, combinations of retrofit measures, and climatic zones. Finally, some tools with pre simulated databases do not rely on advanced energy simulations, which make their results approximative. Tables 4 and 5 describe the characteristics of tools using pre-simulated databases to predict energy consumption.

3.2.1. Quickscan Tool

The Quickscan tool was as part of the European funded Interreg NWE ACE-Retrofitting (Accelerating Condominium Energy Retrofitting) project. The tool allows homeowners to get an initial overview of suitable retrofit measures that could be installed within their building. Quickscan uses a database of factsheets and a routing method to provide users with appropriate solutions according to their responses to questions about their homes. Each city or region from Europe can adapt the content of Quickscan tool by for instance changing the text, images and language used as well as the visual design [7].

3.2.2. SWAHO (Sustainability Weighting Assessment for Homeowners)

SWAHO was developed by researchers from the University of British Colombia, Canada [38]. The tool aims to provide easier sustainable decision-making for homeowners for their green renovation projects. The tool was created using Microsoft Excel with Macros (Visual Basic for Applications, VBA). It evaluates 48 renovation actions in terms of 12 sustainability criteria using a knapsack problem technique to optimize solutions. A pre-simulated database in excel contains the evaluation of the retrofit solutions and the user has the option to adjust the prices. The majority of existing online tools that aim to help homeowners to invest in energy efficiency measure evaluate retrofit solutions in terms of financial, energetic, and environmental criteria. SWAHO presents the particularity to take into consideration social criteria. Furthermore, SWAHO allows homeowners to indicate their priorities among social and environmental criteria.

3.2.3. ALICE (Amélioration des Logements en Intégrant les Contraintes du Confort d'Été)

ALICE is an excel tool developed by the French Scientific and Technical Center for Buildings. It offers the possibility of analysing the impact of different thermal renovation configurations as well as the impact of different behavioural scenarios of building users on summer comfort. Two thousand four hundred dynamic thermal simulations have been carried out to calculate the interior temperature of a range of dwellings representative of the most common building typologies in France. Users can assess and compare the impact of different renovation solutions on summer comfort [39]. While the majority of decision tools focus on energy savings and carbon reduction, ALICE presents the specificity to take into consideration summer comfort, which is especially interesting in the current context of global warming and summer heatwaves.

Table 4. A list of the toolkits using pre-simulated databases with the general input requirements.

General Information	6. Quickscan Tool	7. SWAHO (Sustainability Weighting Assessment for Homeowners)	8. ALICE	9. INSPIRE	10. 1 2 3 Réno	11. Energihjem.dk
URL	nweurope.eu/projects/project-search/accelerating-condominium-energy-retrofitting-ace-retrofitting/#tab-4			zenodo.org/record/3256270#.YHgh8-hKiyI	123reno-med.eu/votre-projet.html	energihjem.dk/beregner/#/
Developer/Sponsor	European funded Interreg NWE ACE-Retrofitting	University of British Colombia	French Scientific and Technical Center for Buildings	European Community's Seventh 455 Framework Programme	European project MARIE	AB Gruppen AS
Type	Web-based	Excel sheet	Excel sheet	Excel sheet	Web-based	Web-based
Location	Europe	Canada	France	Europe	Mediterranean and alpine regions in France	Denmark
Postcode						X
Calibration						
Utility bills						
Occupant behaviour						
Preferences of user		X				
Simple building characteristics	X		X	X	X	X
Simple system characteristics	X		X	X		
Detailed building characteristics			X	X		
Detailed system characteristics			X	x		

Simple building characteristics: This includes all or some of the following inputs: building type, age of the building, floor area, and the number of residents. Simple System Characteristics: This includes heating system, wall insulation, window type, and floor and roof characteristics. Detailed System and Building Characteristics goes beyond that listed in the simple category.

Table 5. A list of the toolkits using pre-simulated databases and highlighting energy calculation methods, main features, generation and range of retrofit measures, evaluation criteria and indications on financial support.

Tools	Calculation Engine	Features	Retrofit Solution Categories	Generation of Retrofit Solutions	Evaluation Criteria	Indications on Financial Support
6. Quickscan tool	Uses a database of factsheets and a routing method.	Allows homeowners to get an initial overview of suitable retrofit measures. Each city or region from Europe can adapt the tool.	Building envelope, energy efficient equipment for heating and hot water.	Automatically provides a list of renovation solutions that are evaluated individually.	Typical cost (qualitative), annual savings (qualitative)	Does not provide indications on funding options.
7. SWAHO (Sustainability Weighting Assessment for Homeowners)	Evaluates 48 renovation actions in terms of 12 sustainability criteria using a knapsack problem technique to optimize solutions. A pre-simulated database in excel contains the evaluation of the retrofit solutions in terms of various criteria.	Takes into consideration social criteria. Homeowners have the opportunity to indicate their priorities among social and environmental criteria. Generate solutions according to the available user's budget.	Building envelope, energy efficient equipment for heating, hot water and cooling electric lighting, renewable energy	Users select retrofit solutions.	Estimated cost ($), acoustic comfort, thermal comfort, luminous comfort, indoor air quality, functionality, durability, occupant control, safety and security, aesthetics, energy saving, water saving, waste optimization	Does not provide indications on funding options.
8. ALICE	2400 dynamic thermal simulations have been carried out to calculate the interior temperature of a range of dwellings representative of the most common building typologies in France.	Evaluates the impact of different renovation solutions on summer comfort.	Building envelope	Users select retrofit solutions.	Indoor temperature during a typical day (°C)	Does not provide indications on funding options.
9. INSPIRE	A simulation-based database organised in excel sheets collects information on the energy performance, installation and actual costs and environmental impact of 250,000 different renovation packages.	Provides highly accurate results. Takes into consideration 7 different climates representative of EU climates.	Building envelope, energy efficient equipment for heating and hot water, renewable energy	Suggest an improvement package that takes into consideration integrated effects.	Energy performance, installation and actual costs, environmental impact	Does not provide indications on funding options.
10. 1 2 3 Réno	Uses a database of pre simulated calculations, which were carried out on 14 housing typologies representative of the Mediterranean basin.	Generates energy improvement packages according to different renovation objectives and different typologies of homes.	Building envelope, energy efficient equipment for heating, hot water, and cooling, occupant behaviour change	Suggest an improvement package that takes into consideration integrated effects.	Investment cost (€), energy saving (%), EPC band score (kWh.ep/m^2/year)	Does not provide indications on funding options.
11. Energihjem.dk	Results are based on EPC reports from the Danish Energy Agency	Based on the address provided by the user, the calculator indicates energy improvements that the EPC report recommends for that house.	Building envelope, energy efficient equipment for heating and hot water, renewable energy.	Users select retrofit solutions.	EPC band score, investment cost (Danish Kroner (DKK)), annual savings (DKK), value increase (DKK) loan amount.	Provides detailed calculations on energy loans.

3.2.4. INSPIRE

INSPIRE is a European funded project that aimed to develop a methodology to generate accurate data on retrofit solutions for typical buildings in different climatic conditions. A simulation-based database organised in excel sheets collects information on energy performance, installation and actual costs and environmental impact of different renovation packages applied to the building envelope and the HVAC system of residential buildings belonging to different climates and construction periods [40]. Energy performance results are gathered in a database that allows comparing solutions, spanning over a range of more than 250,000 combinations. The retrofit solutions comprised in the database cover envelope aspects, HVAC system behaviour, four energy demand levels, four generation devices, three distribution systems, three PV systems and two slopes can be combined, and results are available for each configuration [41]. One of the main particularities of this tool compared to similar existing tools is its ability to take into consideration seven different climates representative of EU climates.

3.2.5. 123 Reno

123 Réno online tool was developed as part of the European project MARIE [6]. The tool generates energy improvement packages according to different renovation objectives and different typologies of homes in the Mediterranean and alpine regions in France. The user starts by selecting a specific renovation project objective. Eight objectives are available including reduction of energy consumption, improvement of thermal comfort, improvement of acoustic comfort, and improvement of indoor air quality. Then, the user indicates the type of building and its location. Finally, the tool generates an improvement package and provides fact sheets explaining the most appropriate energy improvement solutions. Energy retrofit packages are evaluated in terms of investment cost, energy saving in percentage, and EPC band score before and after renovation. The renovation packages aim to reach EPC band score A or B for single-family houses and the certification "BBC-effinergie Rénovation" for apartment buildings. 1 2 3 Réno uses a database of pre simulated calculations, which were carried out on 14 housing typologies representative of the Mediterranean basin. The standard calculation method 3CL developed by the French ecological transition agency is used to estimate EPC band score of single-family houses before and after renovation. The standard calculation method TH-C-E-ex (French thermal regulation) and the method 3CL are both used to calculate energy saving in apartment buildings.

3.2.6. Energihjem.dk

Energihjem.dk has been developed by AB Gruppen AS. Based on the address provided by the user, the calculator indicates energy improvements that the EPC report recommends for that house. The user can choose the energy solutions that the EPC suggests and gets an estimate of the annual savings and investment costs. If the user selects all the proposed energy solutions, the tool indicates the maximum calculated energy potential and the highest energy category that the home can achieve. Results are also presented in a detailed calculation mode where each solution is evaluated in terms of EPC band score (before and after renovation, investment cost (Danish Kroner (DKK)), annual savings (DKK), value increase (DKK), and loan amount [42].

3.3. Simplified Normative Calculation Methods

Normative calculation methods are based on a set of calculation standards developed by the European Committee for Standardization (CEN) and the International Organization for Standardization (ISO). Simplified methods calculate the energy performance of new and existing buildings according to a set of normative assumptions about functional building category, assumed usage scenario, system efficiency, etc. [43]. The application of standard calculation methods has many benefits, such as effectiveness, transparency, and reproducibility, representing a good alternative for energy performance rating [44]. However, as normative methods do not take into consideration thermal zones and user's behaviour in the assessment of energy consumption, imprecisions in calculations are very common [45]. Tables 6 and 7 describe the characteristics of tools using normative calculation methods to predict energy consumption.

3.3.1. Energy Efficiency Calculator

Energy Efficiency calculator was developed by the UK government to help homeowners understand how their houses and flats use energy, and how their home's energy use could be improved. This tool relies on Standard Assessment Procedure (SAP), which is the methodology used by the UK Government to assess and compare the energy and environmental performance of dwellings. The assessment is based on standardised assumptions for occupancy and behaviour. This tool is linked to England EPC's database, simply by indicating their postcodes, users can find information about the energy efficiency of their homes from the EPC database [46]. Furthermore, it allows users to save time as the majority of inputs are already available from the EPC database. Energy Efficiency Calculator takes into account occupant behaviour such as the temperature of heating, which makes the results accurate. This tool evaluates retrofit solutions in terms of investment cost and saving per year and also indicates how to finance the renovation work.

3.3.2. Home Energy Check (HEC)

Home Energy Check was created as part of the Request2Action research project which is co-funded by Intelligent Energy Europe. HEC allows Greek homeowners to simulate energy behaviour, rating, and CO_2 emissions of their homes through the input of the necessary characteristics typology, geographical area, characteristics of heating/cooling systems, etc. The tool also allows users to select between different renovation solutions including renewable energy alternatives and visualise the results in terms of energy consumption, energy performance category, total cost, and CO_2 emissions. The tool uses a three-layer architecture concept: the user-layout, the formatting, and the calculations-application server layers, and the analysis platform uses the TEE KENAK software. TEE-KENAK software is a certification software used in Greece to issue the Energy Performance Certificate (EPC) for a building [8].

3.3.3. Sanierungskonfigurator

Sanierungskonfigurator calculates the final energy demand and CO_2 emissions before and after renovation and helps users to identify funding opportunities and local contractors. This tool was developed by the Federal Ministry for Economic Affairs and Energy of Germany [47]. The calculation of energy value is based on the German standards DIN V 4108-6 and DIN V 4701-10. To keep the number of entries low, assumptions are made for the geometric dimensions and the heating system. Therefore, results are approximate and do not correspond to real energy consumption or an EPC certificate.

Table 6. A list of the toolkits using normative calculation methods with the general input requirements.

General Information	12. Energy Efficiency Calculator	13. Home Energy Check (HEC)	14. Sanierungskonfigurator	15. SOLIHA Autodiagnostic	16. Verbeterjehuis	17. 4ECasa
URL	simpleenergyadvice.org.uk/energy-efficiency/reduce-bills	energyhubforall.eu/HEC.html	sanierungskonfigurator.de/start.php	eco-renov.soliha.fr/autodiagnostic/	verbeterjehuis.nl/	portale4e.it/4ecasa/gioco1.aspx
Developer/Sponsor	UK government	Request2Action project	Federal Ministry for Economic Affairs and Energy of Germany	SOLIHA, "Solidaires pour l'habitat"	Milieu Centraal, Netherlands Enterprise Agency and the Ministry of the Interior and Kingdom Relations	Request2Action project
Type	Web-based	Web-based	Web-based	Web-based	Web-based	Web-based
Location	England	Greece	Germany	France	Netherlands	Italy
Postcode	X					
Calibration	X				X	
Utility bills						X
Occupant behaviour	X					
Preferences of user						
Simple building characteristics	X	X	X	X	X	X
Simple system characteristics	X	X	X	X	X	X
Detailed building characteristics	X	X	X	X	X	X
Detailed system characteristics	X	X	X	X	X	X

Simple building characteristics: This includes all or some of the following inputs: building type, age of the building, floor area, and the number of residents. Simple System Characteristics: This includes heating system, wall insulation, window type and floor and roof characteristics. Detailed System and Building Characteristics goes beyond that listed in the simple category.

Table 7. A list of the toolkits using normative calculation methods and highlighting energy calculation methods, main features, generation and range of retrofit measures, evaluation criteria and indications on financial support.

Tools	Calculation Engine	Features	Retrofit Solution Categories	Generation of Retrofit Solutions	Evaluation Criteria	Indications on Financial Support
12. Energy Efficiency Calculator	Relies on Standard Assessment Procedure (SAP)	The tool is linked to England EPC's database, which allows users to save time as the majority of inputs are already available from the EPC database.	Building envelope, energy efficient equipment for heating and hot water, occupant behaviour change	Users select retrofit solutions.	Current EPC band score, investment cost (£), saving per year (£)	Indicates funding options that are directly related to the selected retrofit solutions.
13. Home Energy Check (HEC)	Uses the software TEE KENAK, which is a certification software used in Greece to calculate EPCs for residential buildings.	Allows Greek homeowners to simulate energy behaviour, EPC rating and CO_2 emissions of their homes.	Building envelope, energy efficient equipment for heating, hot water and cooling, electric lighting, renewable energy	Users select retrofit solutions.	Primary energy consumption (kWh/m^2yr), energy performance category of the building/house (A, B, C, . . .), energy saving (%), reduction of CO_2 emissions (%), total cost (€)	Indicates funding options that are not directly related to the selected retrofit solutions.
14.sanierungskonfigurator	Calculates energy value according to the German energy standards DIN V 4108-6 and DIN V 4701-10.	Provides homeowners information on potentialities and current energy consumption of their homes.	Building envelope, energy efficient equipment for heating and hot water, renewable energy	Users select retrofit solutions.	Investment cost (€), final energy demand before and after renovation (kWh/m^2yr), primary energy consumption before and after renovation (kWh/m^2yr), CO_2 emissions (kg/m^2yr)	Indicates funding options that are directly related to the selected retrofit solutions.
15. SOLIHA autodiagnostic	Uses the EPC calculation engine 3CL-DPE developed by the French ecological transition agency to estimate the EPC band of homes before and after renovation.	Estimates EPC band of homes before and after renovation. It takes into consideration houses and apartments. It considers a comprehensive typology of walls, windows, floors, and roofs. It generates solutions according to the available user's budget.	Building envelope, energy efficient equipment for heating, hot water and cooling, renewable energy	Users select retrofit solutions.	Investment cost (€), yearly energy consumption, EPC (DPE in French) before and after renovation (kWh/m^2yr), CO2 emissions before renovation (kg/m^2yr), payback period (years)	Indicates funding options that are not directly related to the selected retrofit solutions.
16. Verbeterjehuis	Calculations are based on the standard: ISSO 82.3, which is based on the average use of heating and hot water.	Calculates gas consumption according to the data provided by the user.	Building envelope, energy efficient equipment for heating and hot water, renewable energy	Users select retrofit solutions.	Energy label (poor, moderate, good), total investment (€), saving per year, CO_2 emissions per year before and after renovation (kg), energy costs per year before and after renovation (€), gas consumption before and after renovation (m3), electricity consumption before and after renovation (kWh)	Does not provide indications on funding options.
17. 4ECasa	The assessments of energy savings are performed using a simplified normative calculation method developed by ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development).	Indicates retrofit solutions for building envelope and heating system according to current houses' conditions. It takes into account technological criteria.	Building envelope, energy efficient equipment for heating and hot water	Users select retrofit solutions.	Energy saving (qualitative), economic saving (qualitative), complexity of work (qualitative), carbon reduction (%)	Does not provide indications on funding options.

3.3.4. Verbeterjehuis

Verbeterjehuis is a web application that was developed by the independent information organization Milieu Centraal, in collaboration with the Netherlands Enterprise Agency and the Ministry of the Interior and Kingdom Relations [49]. The tool was designed in such a way that homeowners have to answer few simple questions about their home (such as the home type and year of construction) as the majority of questions such as are home area, envelope insulation, hot water system, heating system, and ventilation system are answered by default according to home type and year of construction. However, users have the option to customise their responses. The tool calculates gas consumption according to the data provided by the user and also allows to get more accurate results by asking users to indicate their real gas consumption per year. Based on the data provided by the user, Verbeterjehuis indicates which energy-saving measures the user can implement. Retrofit measures are presented in two categories, improvement options for insulation and improvement options for installations, which includes renewable energy. Retrofit solutions are evaluated in terms of different criteria such as total investment, yearly saving, yearly CO_2 emissions (before and after renovation), yearly energy costs (before and after renovation), gas and electricity consumption (before and after renovation). The tool provides information concerning subsidies and loans according to the location provided by the user. Calculations of energy savings are based on the standard ISSO 82.3, which is based on the average use of heating and hot water.

3.3.5. SOLIHA Autodiagnostic

SOLIHA autodiagnostic aims to provide homeowners with a precise idea of the potentialities and current energy consumption of their homes. It was developed by SOLIHA, "Solidaires pour l'habitat", which is the first French association movement in the home improvement sector. This tool uses the EPC calculation engine 3CL-DPE developed by the French ecological transition agency to estimate the EPC band of homes before and after renovation [48]. It takes into consideration houses and apartments. Additionally, the tool considers a comprehensive typology of walls, windows, floors, and roofs and generate solutions according to the available user's budget. It provides homeowners indications on investment cost, yearly energy consumption, EPC (DPE in French) before and after renovation, CO_2 emissions before renovation and payback period.

3.3.6. 4ECasa

4ECasa is a home energy check tool that has been developed in Italy by the National Agency for New Technologies, Energy and Sustainable Economic Development within the European project Request2Action [50]. The tool indicates retrofit solutions for building envelope and heating system according to current house's conditions. The solutions are evaluated in terms of energy savings, economic savings, the complexity of works, and carbon reduction. The assessments of energy savings are performed using a simplified normative calculation method developed by ENEA (National Agency for New Technologies, Energy and Sustainable Economic Development), considering standard conditions of use of the property. The main particularity of this tool compared to the majority of existing tools is to take into account technological criteria such as the complexity of work.

3.4. Advanced Calculation Methods

Advanced calculation methods use dynamic simulations, which is the most accurate alternative for the assessment of energy performance in buildings. This type of calculation takes into account thermal inertia of walls, variability of the outside temperature, solar radiation, natural ventilation and users' management. However, users of advanced calculation methods need to have energy modelling experience as they should provide detailed data concerning building characteristics and climatic condition, which makes such methods complex to use for homeowners in their energy retrofit project. Tables 8 and 9 describe the characteristics of tools using advanced calculation methods to predict energy consumption.

3.4.1. Home Energy Saver

The Home Energy Saver calculator was the first Internet-based tool for calculating energy use in residential buildings in the US [51]. It calculates heating and cooling consumption using the DOE-2 (version 2.1E), building simulation program (version 2.1E), developed by the U.S. Department of Energy. The estimates break down energy consumption by "end-use" including heating, cooling, water heating, major appliances, small appliances, and lighting. The tool provides detailed evaluations of retrofit solutions in terms of several criteria such as yearly savings, yearly saving in electricity, yearly saving in gas, estimated added cost, yearly carbon reduction, payback period, investment cost, estimated return on investment. Homeowners can modify the energy efficiency assumptions in many cases, as well as the renovation costs and then recalculate the results. Users also have the opportunity to choose between a quick input mode with many assumptions and approximative outputs and a detailed input mode that provides more accurate results, however, resulting in a long analysis and data input time.

3.4.2. HOT2XP

HOT2XP is a desktop application developed by CanmetENERGY. HOT2®XP requires few inputs to indicate a house's energy consumption [52]. The house features are defaulted based on age and location. This tool uses the thermal dynamic engine HOT2000. This tool presents the results in different forms, a full technical report, including monthly results, a simplified graphical homeowner report, adjustment of calculated energy use against utility meter readings, and evaluation of energy retrofit options. HOT2®XP provides accurate results for simple single-family housing stock. However, the software provides approximate outputs when the typologies of houses are more complex as default inputs are only adapted to single-family houses. To accurately simulate different building typologies, users have to change the defaults value, which might be extremely complicated for a simple homeowner.

Table 8. A list of the toolkits using advanced calculation methods with the general input requirements.

General Information	16. Home Energy Saver	17. HOT2XP
URL	homeenergysaver.lbl.gov/consumer/	nrcan.gc.ca/energy/hot2xp/7445
Developer/Sponsor	U.S. Department of Energy	CanmetENERGY
Type	Web-based	Stand-alone
Location	US	CANADA
Postcode	X	
Calibration		X
Utility bills		
Occupant behaviour	X	X
Preferences of user		
Simple building characteristics	X	X
Simple system characteristics	X	X
Detailed building characteristics	X	X
Detailed system characteristics	X	X

Simple building characteristics: This includes all or some of the following inputs: building type, age of the building, floor area, and the number of residents. Simple System Characteristics: This includes heating system, wall insulation, window type and floor and roof characteristics. Detailed System and Building Characteristics goes beyond that listed in the simple category.

Table 9. A list of the toolkits using advanced calculation methods and highlighting energy calculation methods, main features, generation and range of retrofit measures, evaluation criteria, and indications on financial support.

Tools	Calculation Engine	Features	Retrofit Solution Categories	Generation of Retrofit Solutions	Evaluation Criteria	Indications on Financial Support
18. Home energy saver	Calculates heating and cooling consumption using the DOE-2 (version 2.1E), building simulation program (version 2.1E).	Estimates break down energy consumption by "end-use" including heating, cooling, water heating, major appliances, small appliances, and lighting. Allows users to modify the energy efficiency assumptions, as well as the renovation costs. Users have also the opportunity to choose between a quick input mode and a detailed input mode that provides more accurate results.	Building envelope, energy efficient equipment for heating, hot water and cooling, electric lighting.	Suggest an improvement package that takes into consideration integrated effects.	Yearly savings ($), yearly saving in electricity (kWh), yearly saving in Gas (Therms), estimated added cost ($), Yearly carbon reduction (lb. CO_2), payback period (years), investment cost ($), estimated return on investment (%)	Does not provide indications on funding options.
19. HOT2XP	Uses thermal dynamic engine HOT2000	Provides accurate results for simple single-family housing stock.	Building envelope, energy efficient equipment for heating, hot water and cooling, electric lighting	Suggest an improvement package that takes into consideration integrated effects.	Yearly energy consumption (kWh/m^{2}yr)	Does not provide indications on funding options.

4. Discussion

A comprehensive analysis of 19 energy retrofit tools specifically targeting homeowners was performed and presented in a comparative way, specifying their energy calculation methods, main features, generation and range of retrofit measures, evaluation criteria, and indications on financial support. The tools were grouped into four categories: empirical data-driven methods, pre-simulated databases, normative calculation methods, and advanced calculation methods. Due to ambitious energy reduction targets set for the residential sector by many governments [1], the development of web-based energy simulation tools has emerged as an interesting research field in recent years. Energy retrofit toolkit developers targeting homeowners could consider the following issues in future developments:

1. Generation of retrofit solutions

All the analysed tools provide as a result the possible retrofit solutions for a specific situation; however, the generation of retrofit solutions varies. Most of the tools display a list of retrofit solutions that are evaluated separately and invite users to select which actions to implement. Additionally, some tools such as Verbeterjehuis and Energy Efficiency Calculator provide indications on phasing renovation works (e.g., improvement of insulation sol should be selected before improvement of installation actions). Other tools such as Home energy saving tool and MyHomeEQ automatically provides a list of renovation solutions that are evaluated individually. However, the individual analysis of retrofit measures does not take into consideration integrated effects, which are more representative of reality [13]. Individual retrofit measures should be coordinated with each other and the building services technology should be optimised for the requirements of the building. The tools that take into account integrated effects are INSPIRE, 123 reno, Home energy saver and HOT2XP. Most of the reviewed tool suggest renovation actions in relation with the building envelope, energy-efficient equipment for heating and hot water and renewable energy. Few tools such as Home Energy Check (HEC) and Home energy saving tool adopt a more global approach and include additional retrofit solutions in connection with cooling equipment, electric lighting and occupant behaviour change. Furthermore, most available retrofit tools assume that building retrofits are performed all at once and do not consider lifecycle concept and a long-term strategy while in reality, 80–90% of all retrofits undertaken are partial retrofit measures known as step-by-step retrofits rather than complete one-time deep energy refurbishments [53]. Additionally, most existing retrofit tools generate basic improvement solutions (often outdated technologies) and do not suggest deep retrofitting measures according to a high standard such as Passivhaus, which could lead to missed opportunities. In fact, retrofitting processes that begin with shallow measures will not be able to achieve a high level of energy efficiency, which risks compromising the decarbonisation of the building stock by 2050 [54]. Therefore, future tools should have the capabilities to generate long-term integrated renovation packages to reach high energy efficiency standards using cutting edge technologies.

2. Evaluation criteria

As indicated in Tables 3, 5, 7 and 9, most of the reviewed tools evaluate retrofits options taking into consideration energetic, financial, and environmental criteria. Only a few tools take into account technological, social, and aesthetic aspects even though many studies have indicated that such criteria are important to assess the appropriateness of retrofit solutions.

For example, the perceived lack of space to install energy efficiency equipment has been found one of the factors influencing house owners' preferences on energy retrofits [55]. Further studies have shown that the perceived hassle of installation [56] and changes to the visual appearance of the property [57] hinder homeowners from implementing energy efficiency improvements. Other researchers have argued that the intention to create a more comfortable indoor climate motivates homeowners to adopt energy efficiency measures [58].

The tools with the capability to consider other aspects than energetic, financial, and environmental are 4Ecasa, ALICE, and SWAHO. For example, 4Ecasa gives indications on technological criteria such as the complexity of the implementation of selected retrofit solutions using a qualitative scale. Additionally, ALICE evaluates the impact of retrofit solutions in terms of a social criterion which is the summer thermal comfort of residents. The thermal comfort is evaluated using the indoor temperature during a typical day (°C). Finally, SWAHO evaluates retrofit solutions in terms of nine social criteria (acoustic Comfort, thermal Comfort, luminous Comfort, indoor, air quality, functionality, durability, occupant Control, safety and Security, and aesthetics). In this tool, the aesthetic criterion is considered as a part of social aspects. It represents the impact of retrofitting measures on the appearance of the house and is evaluated through a qualitative scale.

Criteria less often considered included technological, social, and aesthetic criteria, suggesting possibilities to develop existing toolkits to evaluate a wider range of indicators.

3. Funding options

The methodology used for the generation of funding options varies between the existing tools. Some tools indicate funding options that are not related to selected retrofit solutions. For example, Home Energy Check (HEC) informs users on national funding programs related to EPCs refurbishment activities while the Home energy saving tool provides information on available loans and green products offered by banks. Few tools indicate funding options that are directly related to selected retrofit solutions. For instance, Energy Efficiency Calculator and Renovation configurator indicate available grants for loft insulation or heating replacement if those retrofit actions are selected by the user. Check je huis is the toolkit with the most complexity and provides detailed calculations on bonuses and energy loans. However, as regulations on financial aid frequently change, the database of the tool must be updated regularly. Many studies have indicated that the lack of information and difficulties of homeowners in finding appropriate financial incentives for their renovation work represents a major barrier for their projects [59–61]. Therefore, it is important that decision tools indicate funding options to encourage homeowners to invest in energy efficiency measures.

4. Traditional buildings

Traditional buildings (defined as those built before 1945) represent a significant part of the building stock in many countries [62,63]. These buildings are a challenge in getting upgraded due to their exceptional aesthetic features. Furthermore, changes in the characteristics of the envelope's layers due to inappropriate insulation could lead to interstitial condensation and thus deterioration of fabric decay and even structural failure. Most toolkits do not suggest specific facade insulation technics adapted to historic buildings. The tool that is most adapted to traditional buildings is 1 2 3 Réno. It suggests only internal facade insulation when a user select a traditional building. Energy Efficiency Calculator also provides indications on adding wall insulation to traditional building. However, none of the existing support tools proposes specific insulation materials (e.g., hygroscopic building materials such as cellulose fibre insulation) to reduce the risk of interstitial condensation in traditional building walls. Future development of toolkits could include specific retrofit solutions adapted to traditional building.

5. Preferences of users regarding evaluation criteria

The majority of selected tools evaluate retrofit solutions in terms of various energetic, economic, and environmental criteria. In multicriteria decision problems, defining the importance of each criterion for decision-makers allows selecting the most appropriate solutions [64]. Furthermore, many studies have indicated that taking into consideration the opinions of homeowners regarding evaluation criteria is essential to select the most appropriate retrofit solutions [65–67]. Most of the existing tools do not take into consideration the preferences of users. Only a few decision tools such as Home energy saving tool and SWAHO allow users to indicate their priorities among various criteria. For, example Home energy saving tool asks users to indicate what is most important for them; lower their energy costs, reduce their environmental impacts, or improve their EPCs band score. Additionally, SWAHO gives the opportunity for users to indicate their priorities among social and environmental criteria. Future tools could consider to include preferences of homeowners in terms of evaluation criteria.

According to the literature (4), awareness and information issues amongst homeowners remain one of the main obstacles that hinder the uptake of energy retrofit schemes. This study provides developers opportunities to improve the quality of the information provided by existing tools, which could enhance their impacts on homeowner's motivation to undertake energy renovation works. Providing access to detailed information such as the type of renovation solution suitable for a particular type of traditional building or the impact of renovation work on the thermal comfort could increase the willingness of homeowners to further proceed in their renovation project.

Equally important is the fact that no tool can do it all. Available tools for homeowners balance the complexity of the data input process, the accuracy of the outcomes, and the simplicity of the interface. It is very challenging to develop a tool that considers simultaneously the generation of long-term integrated renovation packages, a wide range of evaluation criteria including social aspects, detailed funding options, and the specificity of thermal retrofitting of traditional buildings. Hence, this paper only suggests possible opportunities for future developments of retrofit toolkits for homeowners without expecting future tools to address all the mentioned issues at once.

5. Limitations

Like any piece of research, this review paper has limitations, which are to be acknowledged. First, as the literature searches were performed using only English keywords, existing tools in other countries available in other languages were not included in this study, which represents a limitation of the applied methodology. Secondly, subjects of high interest such as energy retrofit tools are heavily investigated and a simple search using Google engine of "energy retrofit tools" generates over ten thousand results. Therefore, a specific search strategy using a precise combination of keywords ("energy simulation, energy retrofit, energy renovation, building energy efficiency" and "tool, toolkit, calculator, web-based application, decision tool" and "home, homeowner, residential buildings") was conducted to whittle down thousands of results and only capture those that are specifically relevant. However, this research strategy has its limitations and some relevant studies might have been missed as the selected English studies of energy retrofit tools focus on countries from Europe and North America while other English-speaking countries with significant energy retrofit policies were not included. Other or additional keywords (e.g., adding the name of countries) might have led to different review results. Hence, the results of the current review stand specifically for the selected studies and given the mentioned limitations, generalization and interpretation of the results should be done with consideration [68].

6. Conclusions

Improving the energy efficiency of the existing building stock is one of the main goals of many countries. To accelerate the retrofitting of existing buildings, the public and private sector have produced a large number of decision tools that aim to encourage homeowners to invest in energy efficiency measures. This research extends the current knowledge by analysing existing approaches and trends used for developing energy retrofitting decision support tools that aim to inspire homeowners. The selected tools were analysed in terms of energy calculation methods, main features, generation and range of retrofit measures, evaluation criteria, and indications on financial support. The findings presented in this review offer the possibility to improve the quality of the information provided by existing tools, which could enhance their impacts on homeowner's motivation to undertake energy renovation works. The review indicates that:

1. Most toolkits use empirical data-driven methods, pre-simulated databases, and normative calculation methods. Advanced calculation methods such as EnergyPlus or eQuest are not often used due to their complexity.
2. Few tools generate long term integrated renovation packages to reach high energy efficiency standards using cutting edge technologies.
3. Technological, social, and aesthetic aspects are rarely taken into consideration, suggesting opportunities to expand existing tools.
4. The generation of funding options varies between the existing tools.
5. Most toolkits do not suggest specific retrofit solutions adapted to traditional buildings.
6. Preferences of homeowners in terms of evaluation criteria are often neglected.

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